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PROPOSED PROGRAM FOR PRODUCING RUST-RESISTANT SUGAR PINE PLANTING STOCK IN CALIFORNIA

FOREWORD

The program herein outlined has been prepared by a small work committee* after several consultations with foresters and technicians representing private, State, and Federal interests. The report that follows recognizes the need for improved management, including specifically the protection of sugar pine from blister rust.

Preparation of this report was recommended at the April meeting of interested cooperators held at Roseburg, Oregon. For more detailed information on status of the work, and for information on discussions leading up to preparation of the report, reference should be made to U. S. Forest Service file designation RZ-CAL, SUPERVISION, Meetings, Rust-Resistant Sugar Pine, specifically to reports of January 18, 1957, February 11, 1957, March 13, 1957, and April 9, 1957. These four reports (copies of agenda and minutes of all-agency meetings held January 25 at Berkeley, California, and April 2 at Roseburg, Oregon) have already been made available.

The report was reviewed by representatives of the lumber industry, other Federal agencies, and the State of California at Sacramento on July 22. The proceedings of this meeting are dated August 2, 1957.

A working committee in Oregon, similar to the California committee, has been simultaneously studying the production of rust-resistant white pine stock to meet Oregon's need. The needs of the two States were correlated at a joint meeting of the working committees in Berkeley on August 16. (The minutes were reported under date of October 2, 1957.) In the August meeting it was decided that separate projects for sugar pine in each State were preferable to a single unified project, but that the separate projects should be correlated carefully to avoid unnecessary duplication. The broad outlines of such correlations were agreed upon at the meeting, and are recorded in the present report.

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OBJECTIVES

The objectives of this report and the program that it outlines are to define the steps and estimate the money needed to develop sugar pine seed and planting stock having potential growth, vigor, and timber qualities that meet all the requirements of economic sugar pine management plus significantly improved resistance to white pine blister rust.

The cost estimates of the project are general and are restricted to the first 10-years of operation. The plan here presented is an optimum one. It lists all the important steps in the production of rust-resistant stock and estimates the cost of each step for an initial period of 10 years. Estimates are totals for all agencies involved. The plan does not necessarily imply that the steps should be undertaken in the precise order outlined, nor that nothing can be done if money in the amounts indicated is not made available. To the extent that funds become available, work will be undertaken on several of the steps.

There are at least two logical approaches to producing rust-resistant sugar pine. Perhaps the most promising one is through selection of naturally resistant trees. Individual trees of prescribed quality (rust-resistant, fast growing, good form, etc.) are carefully selected, tested, and then propagated. The other approach is through hybridization by introducing rust resistance from other white pine species and by growing progeny from the best hybrids. In the present program we recommend that both of these approaches be actively developed.

SCOPE OF 1957 WORK

Using the small amounts of money that have been available, work on a modest scale has been underway for the past 2 or 3 years by the Forest Service. In 1957 two men were employed to search for rust-resistant sugar pines in northern California and southern Oregon (43 candidates were found in California). In 1958 the rust-resistant candidates will be released, fertilized, and posted with appropriate signs. Scion-wood from resistant trees will be collected and grafts made to preserve the selected germplasm.

PART A -- RUST-RESISTANT SUGAR PINE BY SELECTION

1. Search for rust-resistant candidates.
   (Can be done separately in California and in Oregon, or can be pursued jointly as in 1957.)

The search for rust-resistant candidates of sugar pine in northern California should be accelerated. A goal has been set of some 200 to 250 candidates or as many as possible. It is estimated that four 2-man crews working for a period of 4 months will be needed to cover the area in the northern portion of the State where rust-resistant candidates might be found; trees large enough to bear cones are especially needed.

It is recommended that the search be completed as soon as possible (1-3 years) and that one 2-man crew continue to be employed for the next year or two (after the first search is completed) to re-visit the most promising areas. It is strongly recommended that this phase of the program have the highest priority as it is the first logical step and the one on which the remainder of the program is built.

It is estimated that about $5,000 will be needed to keep one 2-man crew out for a 4-month period. A total of about $30,000 will be needed to make a complete survey of which $20,000 should be spent in the first 2 or 3 years, and $10,000 in the succeeding 2 years.

Since a project leader will be needed to supervise actively the entire rust-resistant program as well as to initiate the first steps, provision has been made for his salary and expenses for the full 10-year period at the rate of $10,000 annually.

2. Care of rust-resistant candidates in the field
   (Each State will care for its own candidates.)

The second step in the program is to protect, mark, release, fertilize, and maintain complete records of all present and future rust-resistant candidates. They should be fertilized at least once a year to speed up their growth and hasten flower production. Each candidate should be preserved by a few grafts to prevent accidental loss. These could be preserved at the Institute of Forest Genetics at Placerville. The project leader referred to in step 1 can work part time on this phase of the program.

It is estimated that this part of the project will cost about $1,500 yearly for the first 4 years, and about $1,000 for each of the succeeding 4 years; a total of $10,000.

3. <u>Testing the resistance of rust-resistant candidates.</u>
(Common testing and outplanting sites in Oregon and Washington can be used jointly by the projects in California and Oregon.)

The third step is to test the resistance of each rust-resistant candidate. This is to be done by testing propagules of the candidates (grafts or cuttings) by both artificial and natural inoculation processes. Polyethylene "sleeves" tied to branches in the field may be used as individual inoculation chambers to test immediately selected candidates.

Artificial inoculation can be done in tents at Berkeley. Young sugar pine trees will be used as controls. About 25 grafts or layers from each parent will be used in the test. In case all test material becomes infected, a scale of relative resistance will be set up so that the resistance of one tree can be compared with that of another. This will be determined by counting the needle spots and resulting cankers. Also, candidates found in the future can be tested for resistance and then assigned to their proper place in the scale.

Resistance under natural conditions can be tested by planting the resistant grafts (or trees from layering) in a rust-active site (suggested the Mill Creek plot in southern Oregon). Controls of susceptible grafts and seedlings will be used with the resistant grafts. These tests of natural resistance will be correlated with artificial tests of resistance to determine the field level of resistance needed.

Artificial inoculation of the rust-resistant candidates will be tried in the field. Further work on techniques for this type of inoculation will have to be worked out. Controls will be used as a means of checking on the results. These tests will be conducted for about 3 consecutive years and then watched for another 2 to 3 years. Stray candidates located after the main search has been completed will be tested as found.

It is estimated that step 3 and step 4 will be conducted in conjunction with each other. The bulk of the funds has been set up for step 4 but another $5,000 may be needed to conduct the artificial inoculation phase of the work.

4. <u>Initial propagation of rust-resistant candidates.</u>
(Each State will require outplanting sites.)

The fourth step will be to propagate the germplasm of each rust-resistant candidate through grafting or other vegetative propagation to insure against loss and to serve as a nucleus of future seed orchards (step 6). About 100 grafts from each candidate will be

outplanted in at least three different sites, one-third at each site.

The outplanting sites must be either of State or Federal ownership. The need is for one to three acres at each site with the possibility of increasing this if the need arises. The areas should have an altitudinal range to give a 4 to 6 weeks' difference in flowering. In order to isolate the potential seed orchards from non-resistant pollen sources, the sites should not have native or planted sugar pine in the immediate vicinity.

Three suggested sites are: the forest genetics outplanting area in El Dorado County (Eleven Pines on the Georgetown Divide) with an alternate at the Experimental Forest near Pinecrest on the Stanislaus National Forest. This would be the high elevation site (4,900 feet at Eleven Pines and 5,300 feet at the Experimental Forest). The medium elevation site suggested was the experimental area in the vicinity of Challenge, which is situated at 3,500 feet. A possible alternate would be the State's Magalia Nursery, should it come into State ownership. The low elevation site suggested was at the Parlin Fork State Nursery on the Jackson State Forest (between Willits and Fort Bragg).

These outplanting sites may ultimately be developed as seed orchards as planned under step 6. Only trees whose resistance transmission ability has been proved will be kept. The cost of this work in the first ten years is estimated at about $14,000 ($2,000 annually in the first 4 years and $1,000 in each of the succeeding 4 years.)

5. Test the transmission of rust resistance in candidates. (Joint use of facilities in Oregon and Washington will be made by the projects in Oregon and California.)

Test the ability of individual rust-resistant candidates to transmit rust-resistant characteristics to their progeny. Production of rust-resistant stock for forest planting on a large scale is to be only from seed from proved rust-resistant trees.

Produce seed from rust-resistant candidates either through wind pollination or through artificial pollination:

a. Through wind-pollinated seed with either ovulate cones or with pollen from a resistant parent; the other parent can be any sugar pine of good quality. (Bingham and Squillace believe that the degree of resistance transmitted to the progeny of a rust-resistant candidate can be determined from wind-pollinated seed.)

The estimated cost for collecting seed from wind-pollinated cones (200 trees over a period of 8 years) is $8,000.

b. Through hand pollination, when both parents are rust-resistant candidates. This will give more information on inheritance of resistance. If hand pollination between rust-resistant trees is necessary to determine resistance, then a total of $30,000 will probably be needed.

Test through natural and artificial inoculation the ability of rust-resistant candidates to transmit rust resistance to seedlings (F_1 progeny grown from seed as produced above). Artificial inoculation is most severe and may be too harsh; therefore, results must be correlated with natual inoculation in the field to determine the relative level of resistance needed for field use.

c. By natural inoculation. This is to be done by planting at a highly rust-active site such as the Mill Creek area in southern Oregon. Nursery-run sugar pine seedlings would be interplanted as a control. Highly susceptible ribes would be planted to increase possibility of infection. Total costs are estimated at $6,000.

d. By artificial inoculation. This is to be done in a forest nursery. Both Wind River (Carson, Washington) and Magalia (Magalia, California) Nurseries are suggested. There are advantages in both places.

The estimated cost of testing for resistance in the nursery is $6,000. The tests would fall in the last 6 years of the 10-year period.

6. <u>Develop additional seed orchards of rust-resistant transmitters.</u> (Each State will require its own seed orchards.)

Germplasm propagated and outplanted under step 4 can now be developed for seed orchard purposes. Cut out trees that prove not to be transmitters of resistance and replace with resistance transmitters.

Produce seed from proved rust-resistant transmitters as fast as possible through the use of grafts, layers, and seedling progeny. When seedlings of proved resistant parentage are available, they are to be incorporated into the seed orchards.

Establish about 30 individuals of about 25 different parentages in each seed orchard. Root stocks for later grafting can be established immediately on the orchard sites. In selecting seed orchard locations, insist on best forest sites (Challenge, Georgetown Divide, Big Bar, etc.), flat tillable land somewhat removed from existing sugar pine stands and preferably at the lower altitudinal range of sugar pine. Three or more sites are needed to represent a range of climatic and other conditions, for example, one in the northern Sierra, one in the central or southern Sierra, and one in the northern Coast Ranges. Each site should have about 10 acres. Trees for the seed orchard should be spaced at 25-foot intervals making approximately 75 trees per acre. For 3 sites, the estimated cost would be about $8,000 the first year for orchard establishment, and $2,000 per year for the next 9 years for subsequent maintenance and grafting work.

Estimated seed production is from 100 to 300 pounds of seed per acre (75 trees) in a good seed year. This will produce about 100,000 to 300,000 seedlings per acre of orchard. With seed orchards at low elevation and with fertilization, some cones should be produced every year. Time of initial production of seed in such a seed orchard is unknown.

PART B -- INTERSPECIFIC HYBRIDIZATION TO INTRODUCE RUST RESISTANCE

1. Produce interspecific hybrids between sugar pine and rust-resistant Asian and American white pines.

Both *Pinus armandi* and *P. koraiensis* have been crossed with sugar pine but with considerable difficulty. Only a few hybrid seeds have been obtained, and these had to be germinated by special techniques (embryo culture). These experimental difficulties indicate that the hybridization program should be started on a small scale at first; it can be expanded as new techniques and procedures are developed. The hybrids do grow faster than sugar pine. A small scale mass production of seed of both hybrids should be undertaken in the spring of 1958. Pollen from several sources of each Asian species should be used. Many sugar pine individuals on the Eldorado transect should be used as mother trees. Seeds should be collected in 1959.

If research under way shows that the cross between western white and sugar pine can be effected, then this hybrid also should be made using pollen from rust-resistant western white pines. Other research needs in the interspecific hybridization phase of the program are discussed under section C.

2. Test rust resistance and site adaptability of interspecific hybrids.

Pinus armandi, *P. koraiensis* and certain *P. monticola* selections have all been shown to be highly resistant to blister rust. The level of rust resistance of interspecific hybrids has to be tested both through artificial and natural inoculation. Some of the hybrids should be established in breeding orchards without exposure to rust.

3. Mass produce hybrids having proved rust resistance.

The procedure is exceedingly uncertain until we know more about the ease with which these F_1 hybrids can be produced. Probably F_1 hybrids will be used as parents to produce backcrosses to sugar pine for outplanting.

PART C -- RELATED RESEARCH NEEDED TO SUPPORT TREE SELECTION AND HYBRIDIZATION WORK

Many phases of research are needed to advance the rust-resistant sugar pine program. These phases are broad in scope and can be used widely in the field of forest management, but are particularly important to the rust resistance program. A reasonable program can be built on present knowledge in the field, but adequate research in the phases listed below might very significantly shorten and cheapen approaches to the objectives of the whole program.

1. Research on the fundamental nature of blister rust resistance in white pines.

What are the cytological and the biochemical foundations of rust resistance? What are the genetic and plant-breeding aspects of these bases of resistance? Can the rust resistance of a tree be assayed chemically or cytologically?

Research on possible races of blister rust should be correlated with this part of the work.

2. Study of sugar pine as a species, in terms of its relation to and inherent adaptation to local environment.

This is a sort of seed-source study in reverse. We should determine how far a rust-resistant progeny can be successfully moved from the location (geographic, physiographic, climatologic) of seed collection. We should also answer the question: can intraspecific hybridization be used to transfer rust resistance from proved northern strains of sugar pine to southern strains with unknown reactions to the rust?

3. Vigor tests and quality tests of tree progenies.

This work should include progenies secured both from the "tree selection method" (resistant trees found through search of areas heavily damaged by the rust) and from the hybridization method (obtaining resistant trees through interbreeding sugar pine with resistant species of white pines). The best available growth-vigor tests and wood-quality tests must parallel resistance tests from the start of the program. Such tests must be refined and developed for use on small sugar pine plants of the various sorts (seedlings, cuttings, and grafts) involved in the work.

4. Seed orchard technology.

A great deal of research is needed to determine the best way to develop and to handle a seed orchard to secure maximum yield in the minimum of time. Some of the uncertainties that must be resolved for sugar pine are:

a. Best methods and best seasons for graftage and cuttage.

b. Effects of root-stock and scion-wood on grafted and budded trees.

c. Best silvicultural methods for managing seed orchards and other plantations of grafted trees.

d. Methods of accelerating (forcing) early flowering in sugar pine.

e. Means of increasing and controlling seed production on mature (previously fruiting) trees.

f. Best methods of harvesting seed crops.

5. Vegetative propagation for reforestation purposes.

Mass vegetative propagation offers immediate availability of proved rust-resistant plants with known adaptability to local environment. Some recently discovered chemicals and some long known biologically active chemicals, in combination with recently available "misting" equipment, now offer considerable promise for successful large-scale vegetative propagation. Procedures that should be thoroughly studied and tested are:

a. Mass rooting of common stem cuttings. It has been reported that about one stem cutting out of four of eastern white pine will root in an open nursery bed after chemical treatment, and that about three out of four can be made to root by the best combination of small-scale experimental methods. Sugar pine is known to present much more of a problem.

b. Mass rooting of needle fascicles. Needle fascicles of several species of pines have been rooted experimentally. This method of propagation is being studied by a number of people. Activation of the normally dormant buds in the fascicles may prove to be a tougher problem than merely getting the fascicles to root. If this method could be perfected, planting stock from needle-fascicle cuttings, might become practical. All types of cuttings preclude damage and loss of plants by rust infection of adventitious branches.

c. Machine grafting. Machines are available that very rapidly graft carefully sized scions onto equally sized nursery stock of orchard trees.

d. Air layering. In air layering, a branch attached to the tree is induced to produce roots within a mass of chemically treated peat moss (or other medium) packed around the branch and held in place by a "sleeve" or tube. Some obdurate plant species including sugar pine have been induced to root by this treatment only.

SUMMARY OUTLINE: A TEN-YEAR RUST-RESISTANT SUGAR PINE PROGRAM FOR CALIFORNIA. (WITH TOTAL ESTIMATED COSTS FOR THE DECADE.)

A. Tree Selection for Rust Resistance

A0.	Project Leader	$100,000
A1.	Find Rust-Resistant Pines	30,000
A2.	Care for Resistant Candidates	10,000
A3.	Test Candidates Resistance	5,000
A4.	Propagate and Outplant Selections	14,000
A5.	Test Transmission of Resistance	
a.	Collect Wind-Pollinated Seed	8,000
b.	Produce Hand-Pollinated Seed	30,000
c.	Test by Natural (Field) Inoculation	6,000
d.	Test by Artificial (Tent) Inoculation	6,000
A6.	Develop Seed Orchards	25,000
	(Estimated Annual Cost, Part A -- $23,400.)	$234,000

B. Hybridization for Rust Resistance

B1.	Produce Interspecific F_1 Hybrids	1,500
B2.	Test Resistance of F_1 Hybrids	500
B3.	Mass Produce F_1 Hybrids	10,000
		$ 12,000

C. Supporting Fields Where Research is Needed

C1. Nature of Blister Rust Resistance in Sugar Pine
C2. Variability and Adaptability of Sugar Pine
C3. Progeny Vigor and Quality Tests and Methods
C4. Seed Orchard Technology
C5. Mass Vegetative Propagation Methods

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